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Trends in Automation of Agricultural Field Machinery

CLUB OF BOLOGNA

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see blue.
in everything we do.

Acknowledgements

- ***Mr. Santosh Pitla***, PhD candidate, Biosystems and Agricultural Engineering
- ***Mr. Jeremy Cantrell***, MS candidate, Biosystems and Agricultural Engineering
- ***Mr. Joe Luck***, PhD candidate, Biosystems and Agricultural Engineering

Agenda

- *Machinery Trends*
- Evolving Technologies
- Next Generation Machines
- Control Strategies
- Going Forward

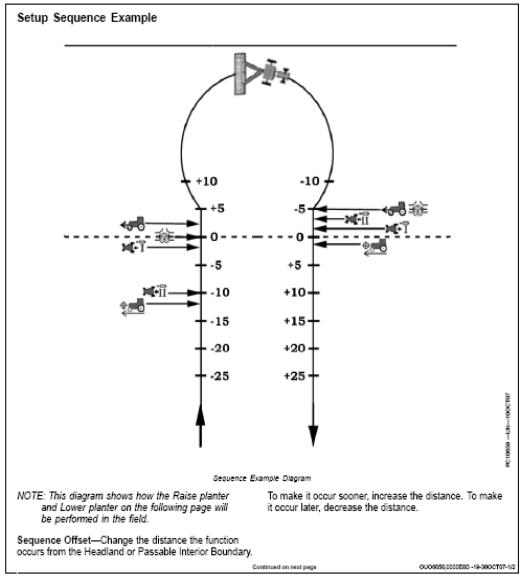
What limits equipment size?

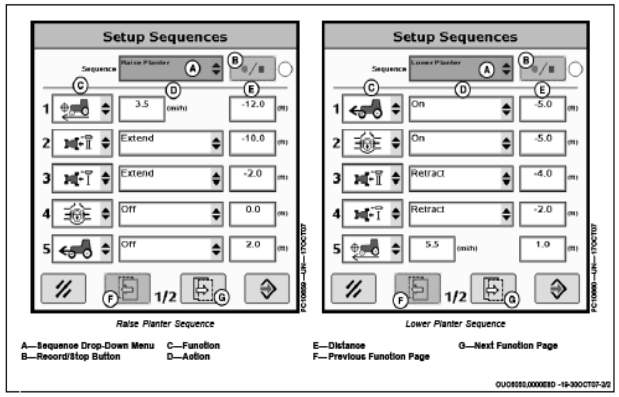
- ***Shipping Weight***
- ***Transport Width***
- ***Available Power***
- ***Total Vehicle Weight***


AGCO MT975B
Engine – CAT C18, 464 kW
Ballasted Mass – 27,200 kg
Fuel Consumption – 125 L/h
Life – 20,000 h
CAT


DEUTZ
FAHR
DEUTZ-FAHR
XXL
1630

intelligent Total Equipment Control
(John Deere iTEC Pro™ Guidance Systems)





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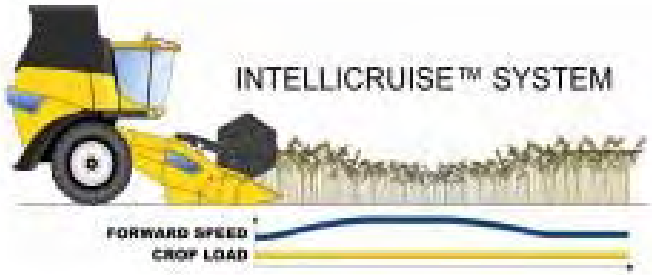
Case IH Axialflow 9120 (Class IX)
Engine – Iveco 12.9L, 390 kW
Grain Tank – 10.1 T
Loaded Mass – 31.6 T
Harvest Rate – 11.8 ha/h
Loading Time – 220 s
Unloading Time – 125 s
Corn Head Width – 12.1 m
Yield – 14.1 T/ha
CASE IH
9120

Harvest Sensing and Control
(New Holland CR 9000)

GRAIN CAM™ PURITY



INTELLICRUISE™

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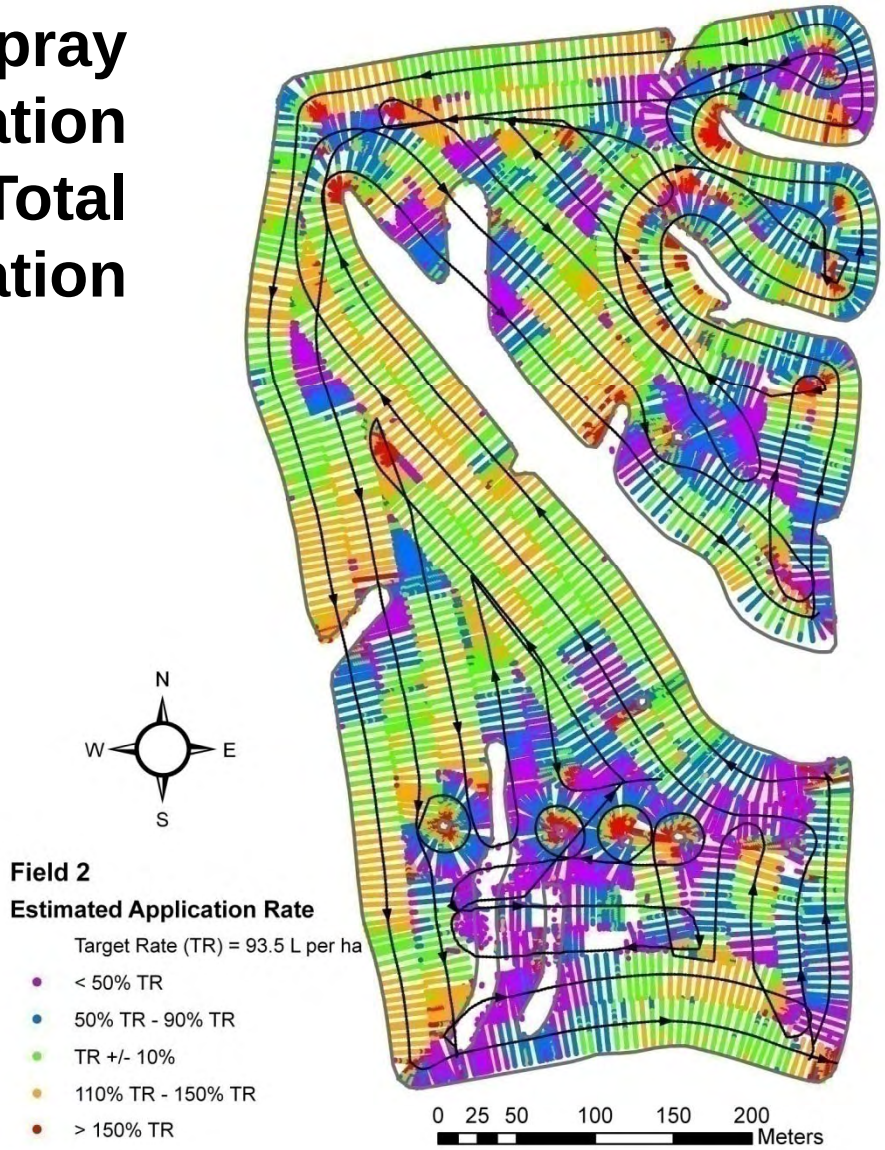
Balzer 2000
Capacity – 54.5 T
Total Loaded Mass – 69.3 T
Unloading Time – 120 s


AGCO RoGator 1396
Boom Width – 36.6 m
Spraying Rate – 88.3 ha/h
Tank Capacity – 4,160 L
Loaded Mass – 17,860 kg

Spray Application Total Variation



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Current Trend Summary

- Machines are ~~controlled~~ operated by humans
- ↑ Machine Size = ↓ Labor Costs
- ↑ Power, mass and storage
- Metering and distribution problems

Current Trend Summary

- **Capitalization ($) remains a problem**
- **Grain producers are forced to farm in combine units**
- **Combine unit – land required to cash flow a new combine (about 2,000 ha for class IX machines)**

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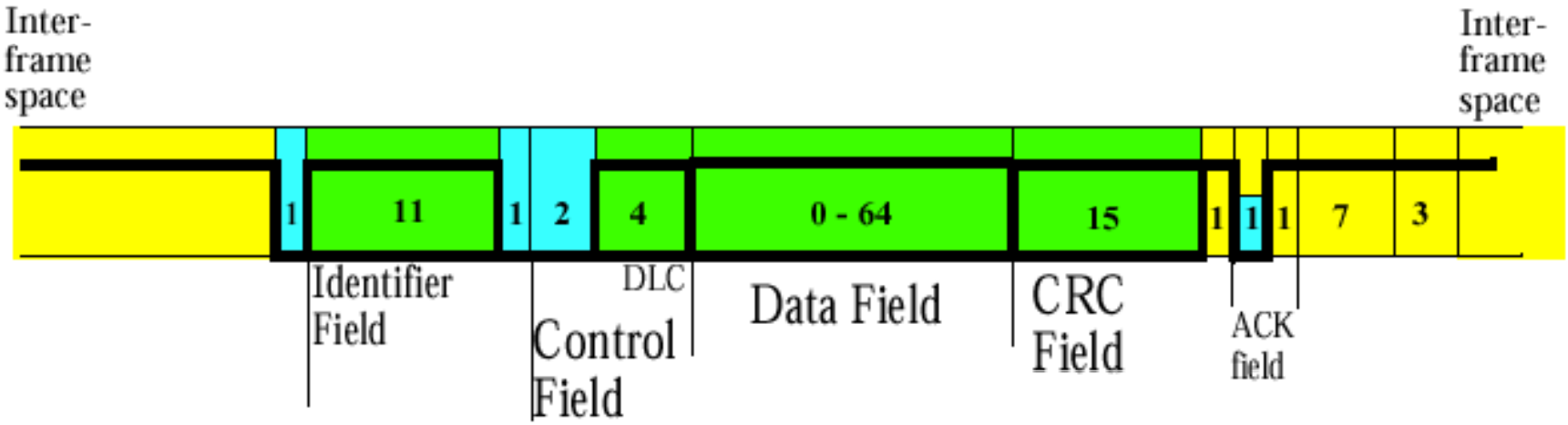
CAN Message Structure

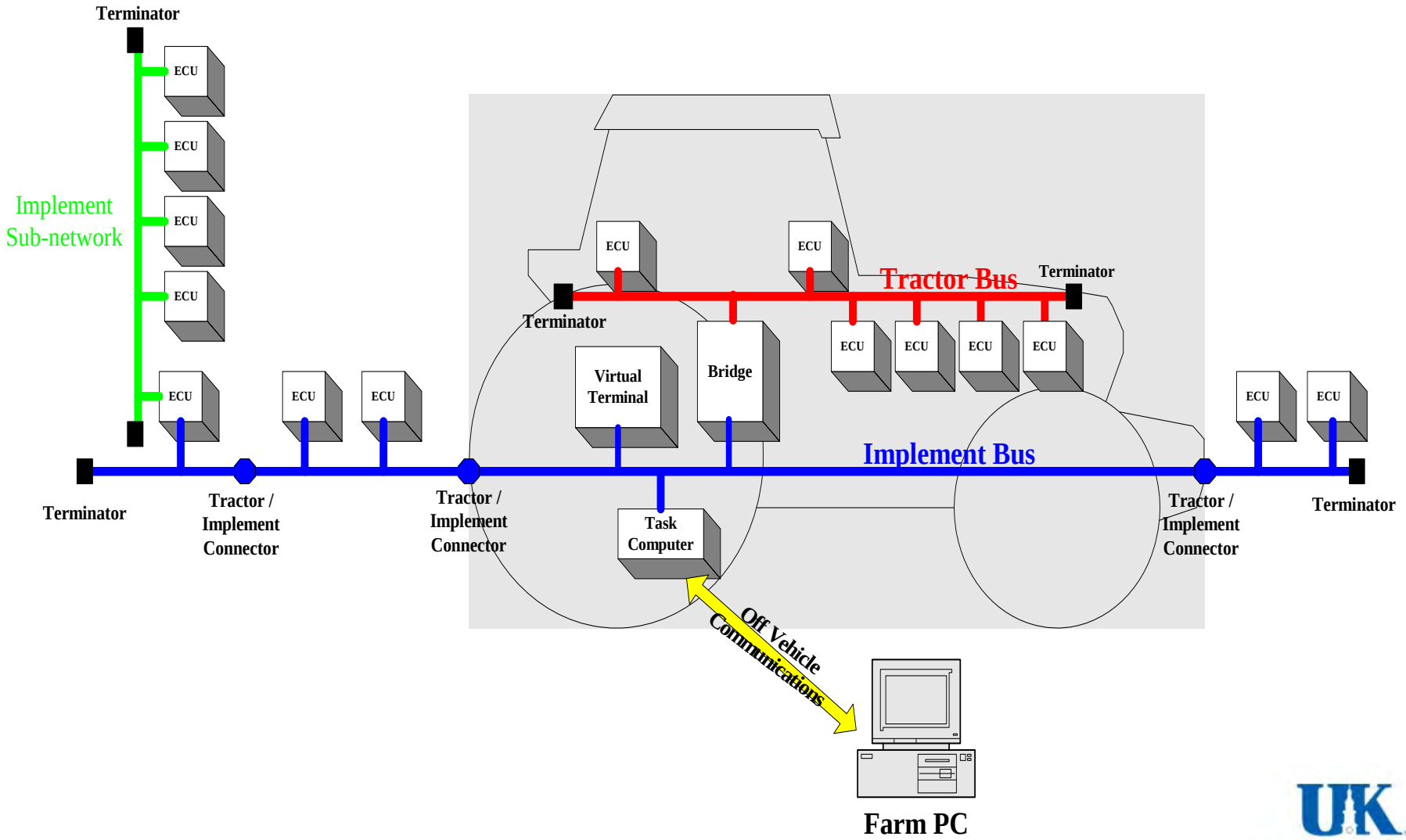
(DIN 9684, SAE J 1939, ISO 11783)



- Priority and Identification field.
- Control field.
- Data field.
- CRC field.
- Acknowledgement field.
- Fixed part.

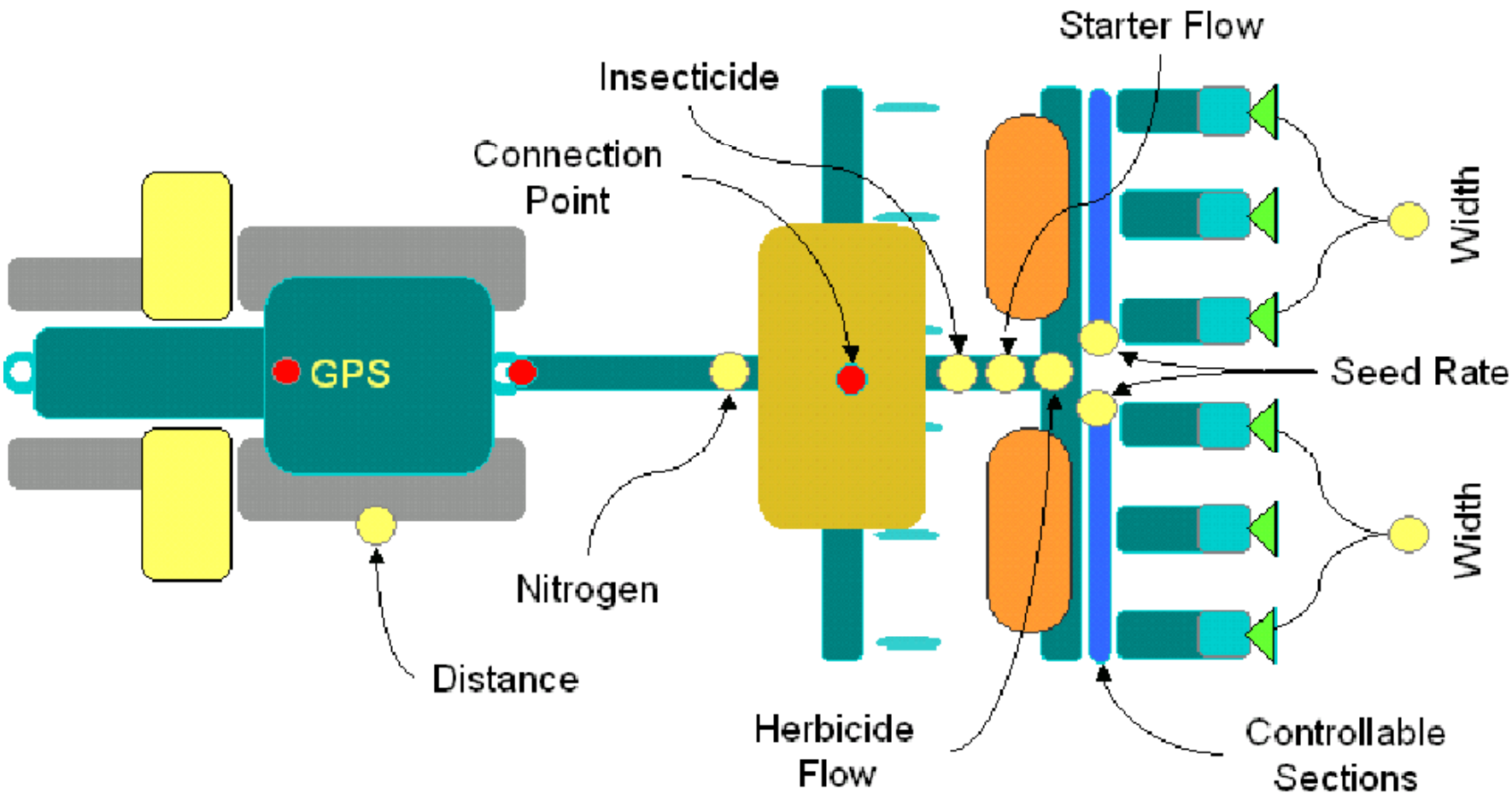
CAN Bus Structure

(DIN 9684, SAE J 1939, ISO 11783)



Field Operations Data Model (FODM)

(Ted Macy – MapShots)



VRS RTK continues to grow!

TRIMBLE DELIVERS MORE ACRES OF SUB-INCH ACCURACY

VRS™ infrastructure network technology is an integrated system that consists of Trimble® GPS/GNSS reference stations spread out over a large area, typically 30-45 miles (50-70 km) apart.

A central server that uses Trimble proprietary software (RTKNet™ or VRS²Net™) creates a correction model for the region covered by the network. Your AgGPS/GNSS receivers communicate using a cell modem with this VRS server to receive RTK type corrections.

VRS SOLUTIONS

TRIMBLE AGRICULTURE—THE LEADER IN RTK

Over 400 million acres under Trimble Ag RTK in the USA

TRIMBLE VRS NOW™ SERVICE

- Leader in network RTK
- Most accepted solution in the world
- Over 3000 reference stations in more than 50 countries

HOW VRS NOW WORKS IS AS SIMPLE AS 1-2-3

1. Power your Ag Rover and cell modem and connect to the VRS Network
2. Trimble VRS Now delivers RTK corrections tailored for your geographic location
3. Complete your farming and precision agriculture operation

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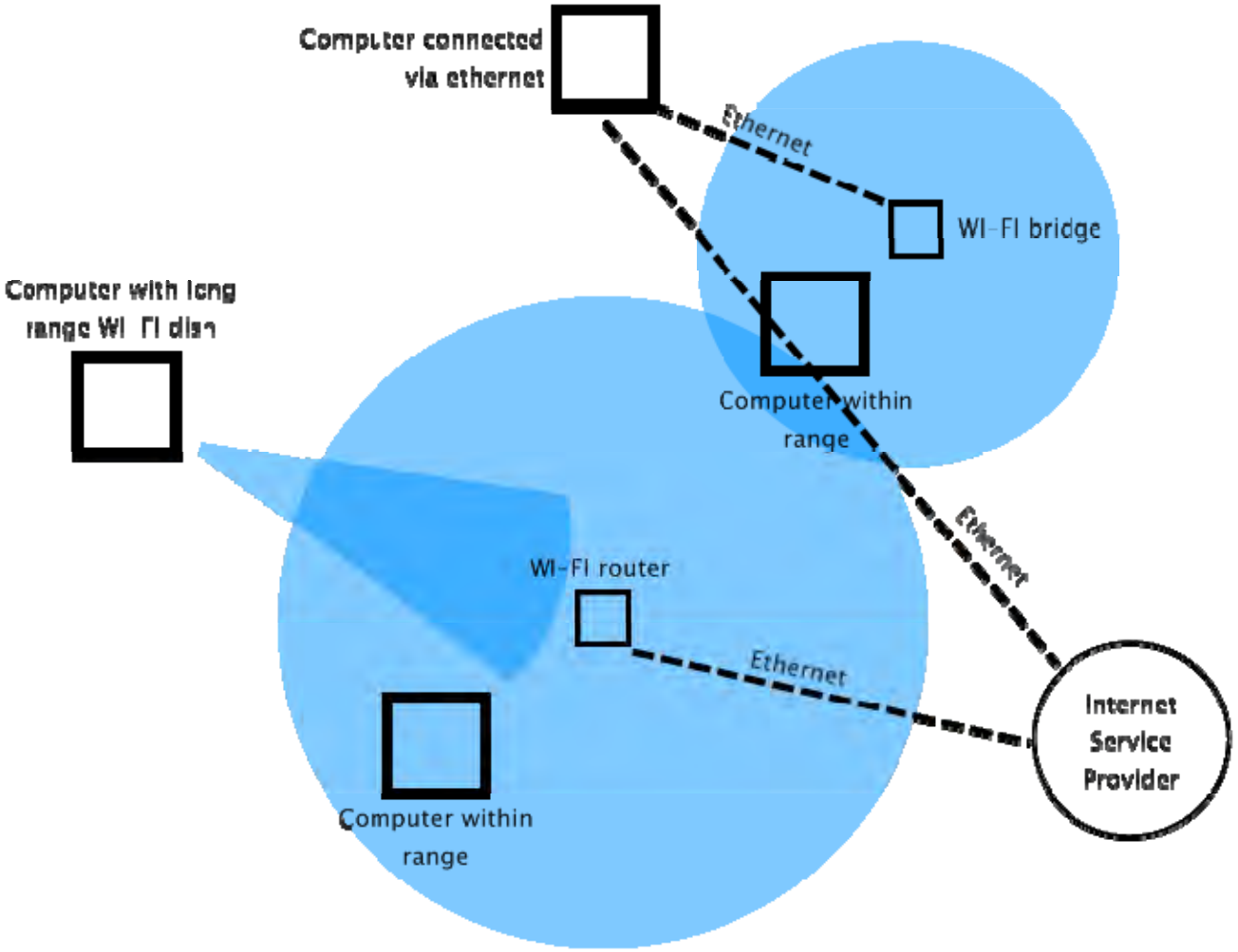
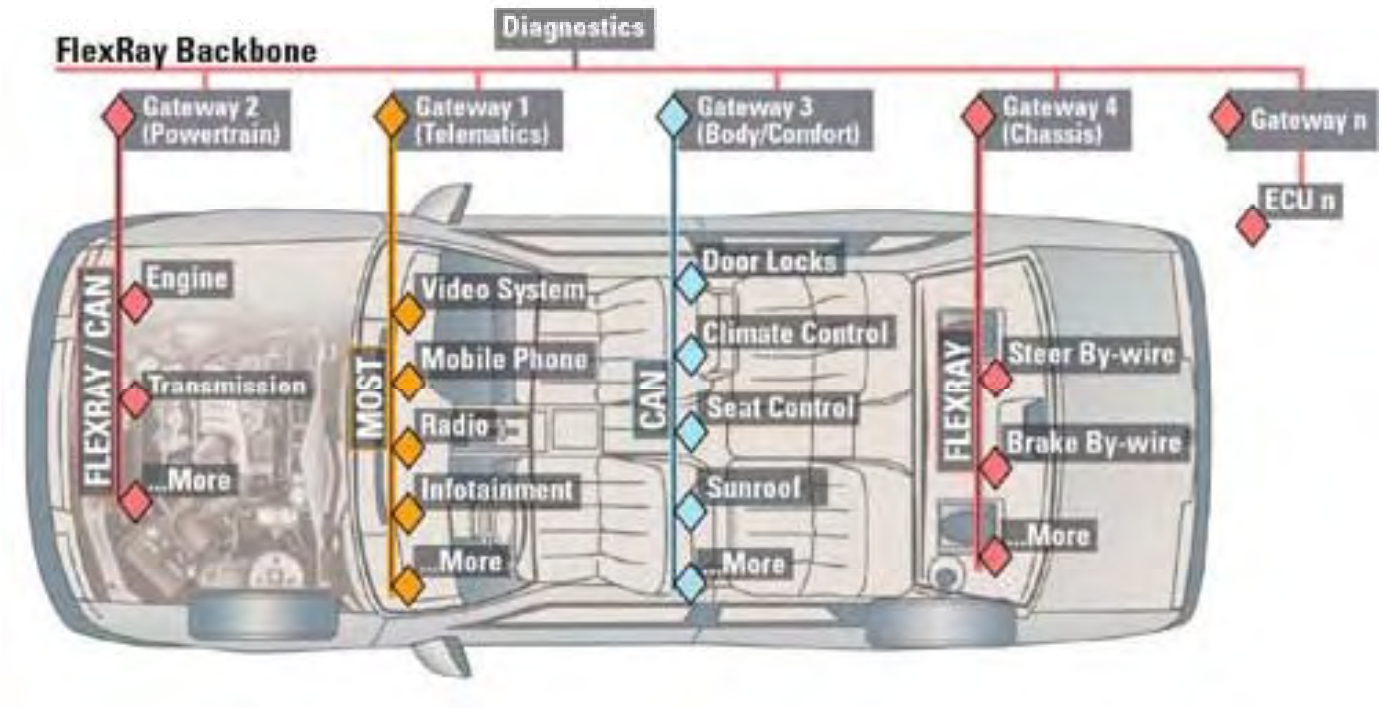
WLAN continues to grow!



FlexRay?



Automotive Design & Production, Gardner Publications, Inc.

Agenda

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Carnegie Mellon University
National Robotics Engineering Center

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John Deere's Autonomous Vehicle Development Program

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Valtra's RoboTrac Concept Tractor
Hannes Seeberg - 2007

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Initial Autonomous Tractor

Darr et al. (2003)

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UKAT II

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UKAT II - Simplified Design w/ Hydrostatic Drive!

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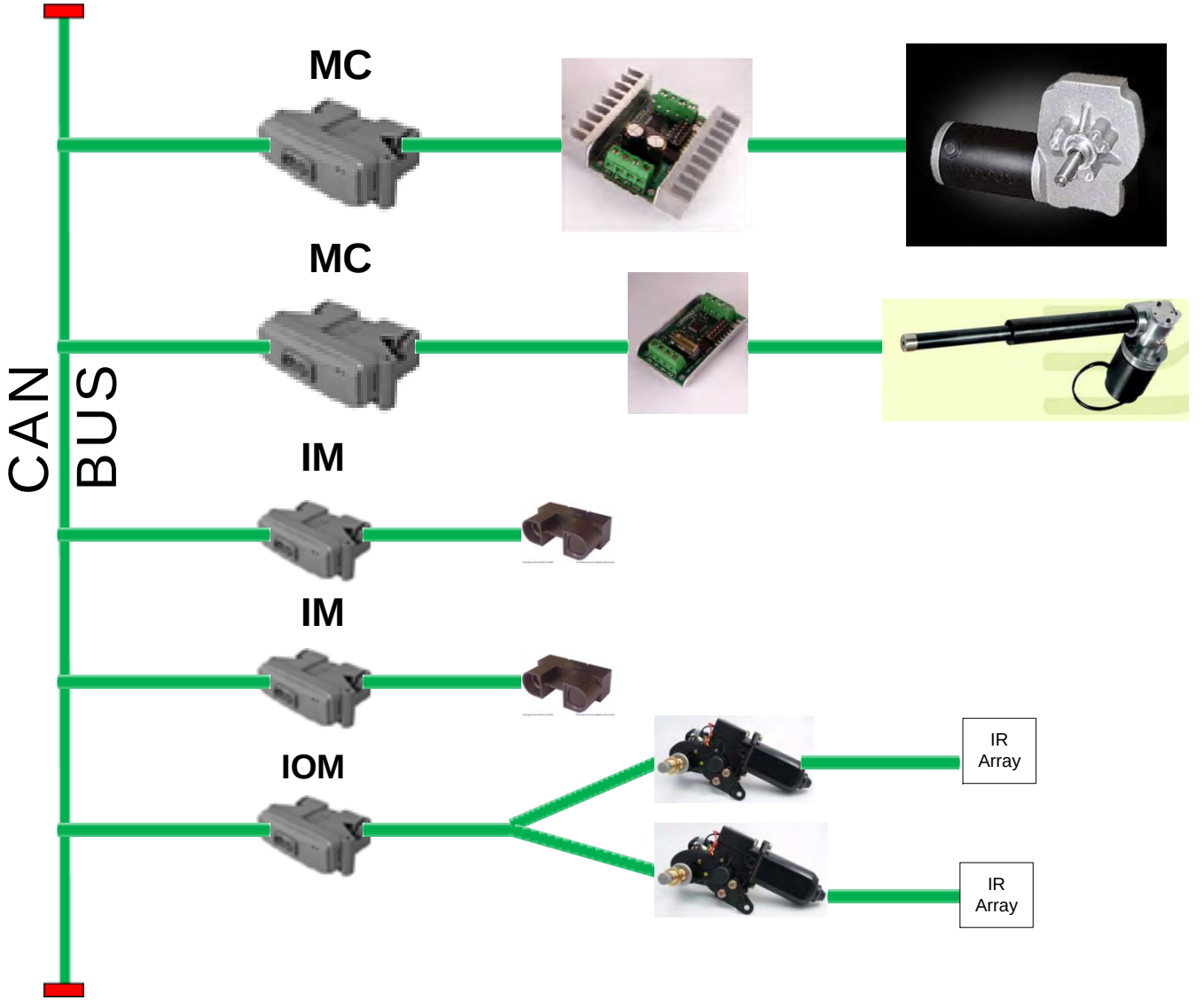
Vehicle Controls Development



Collision Avoidance Sensing

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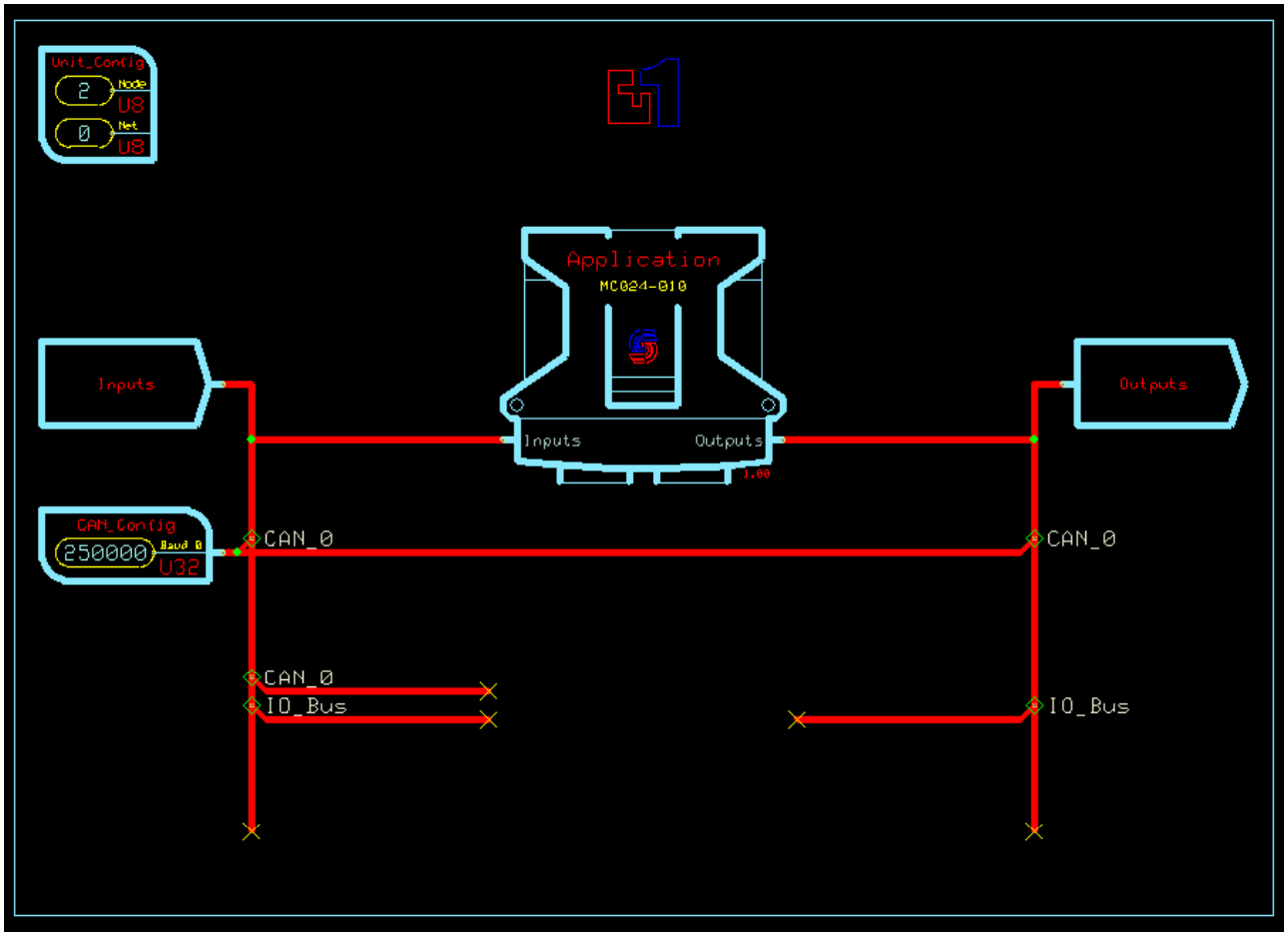
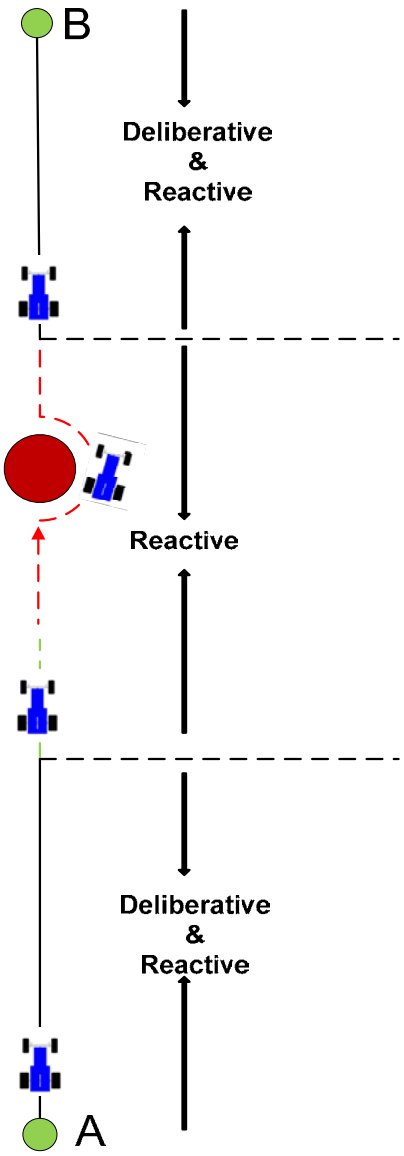
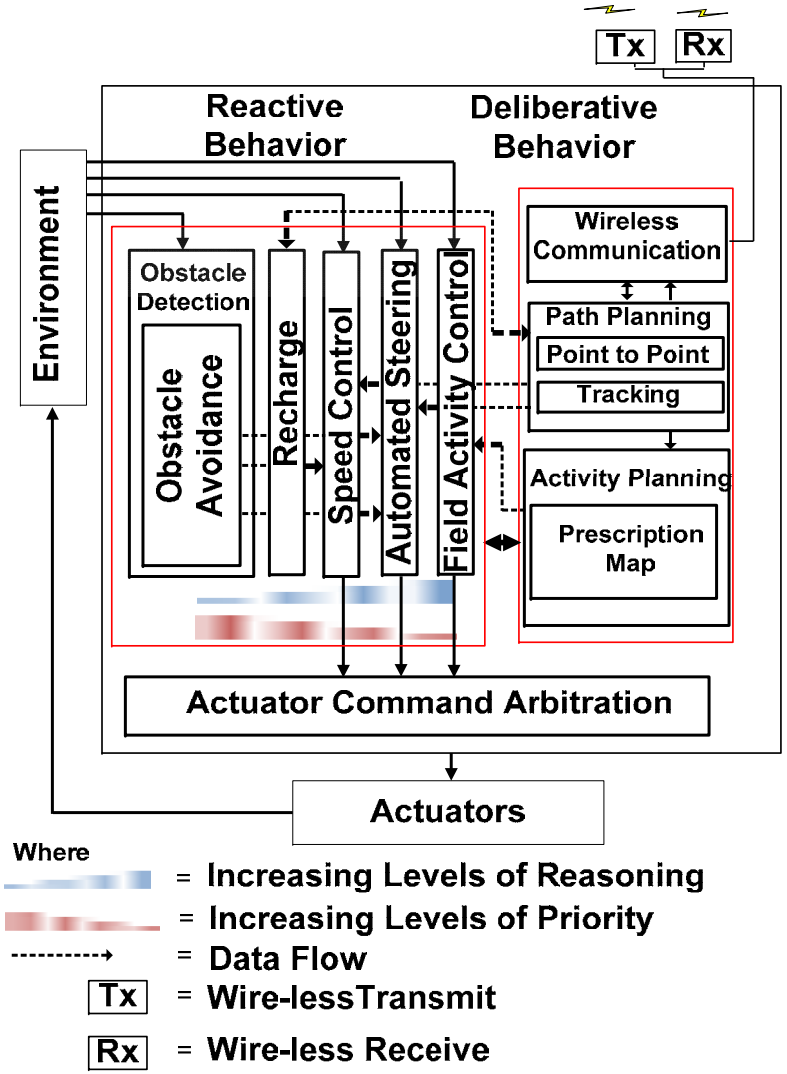
Plus+1 I/O Set-Up GUI



Control Methodology- IRCA





Individual Robot Control Architecture

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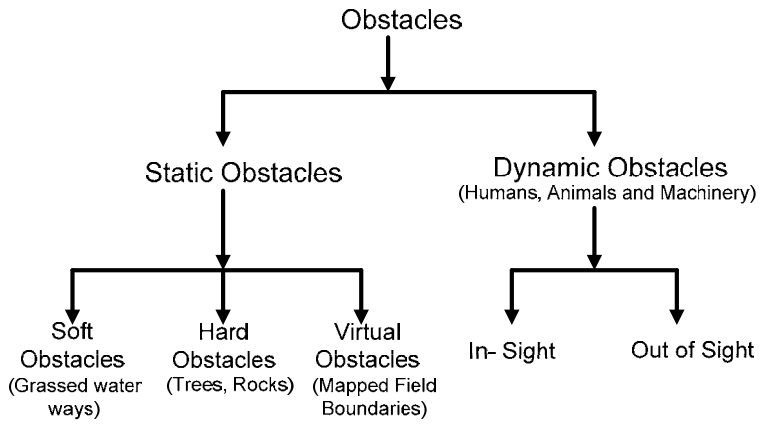
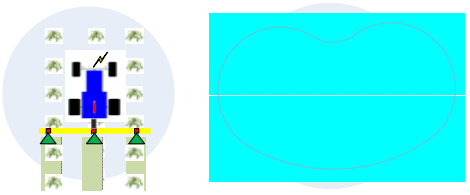
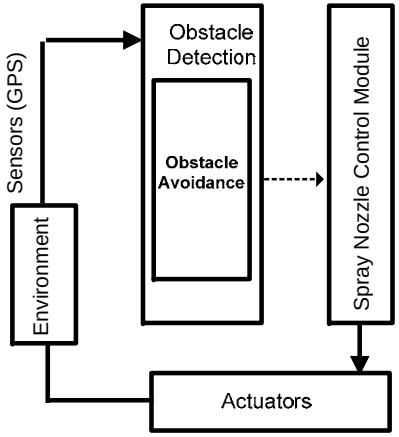
Obstacle Avoidance - IRCA



Soft Obstacle

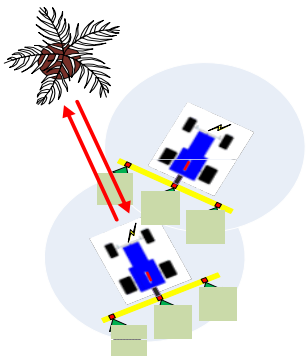


(a) (b)

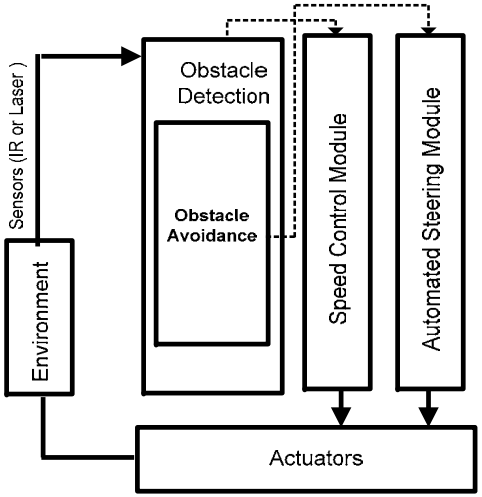


(c)

Hard Obstacle



(a)



(b)

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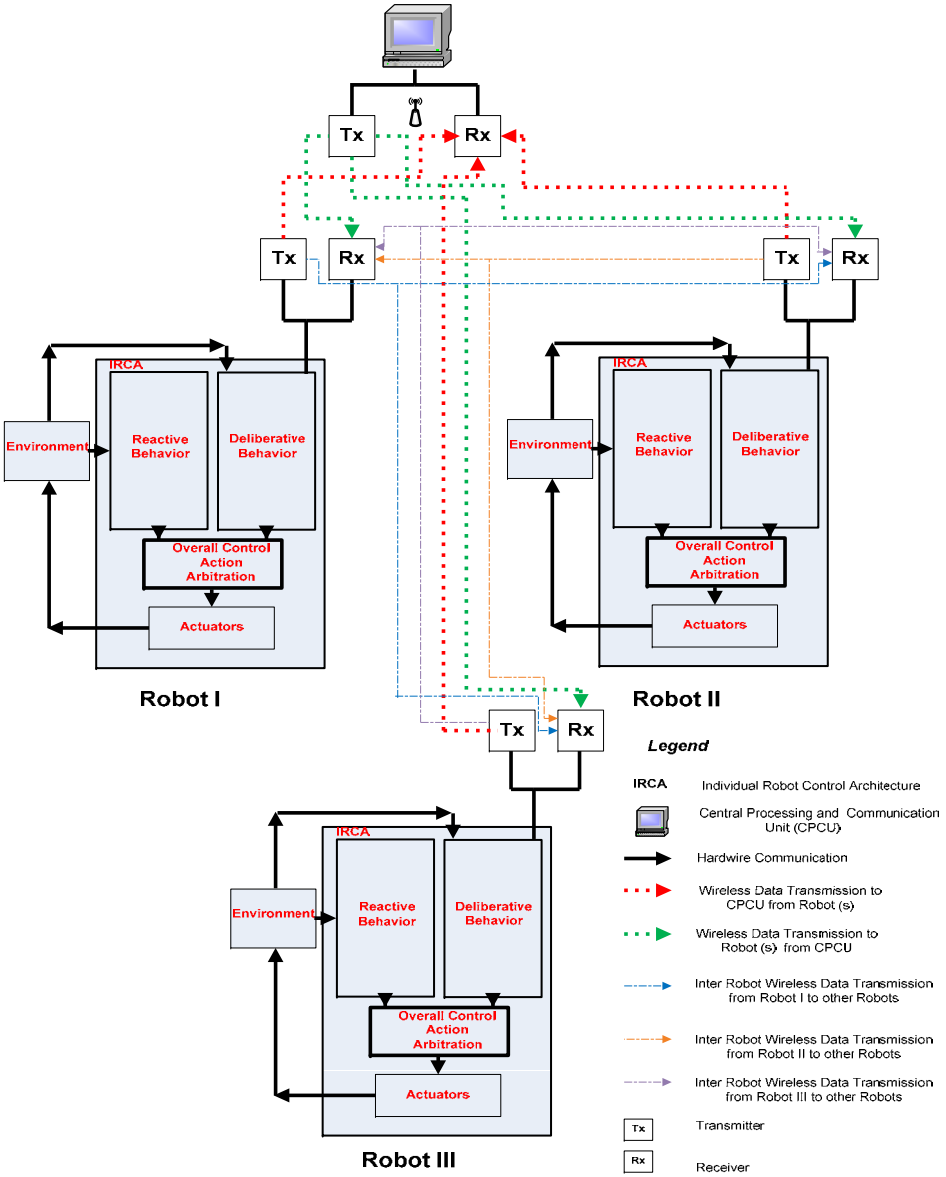
Control Methodology-MRSCA



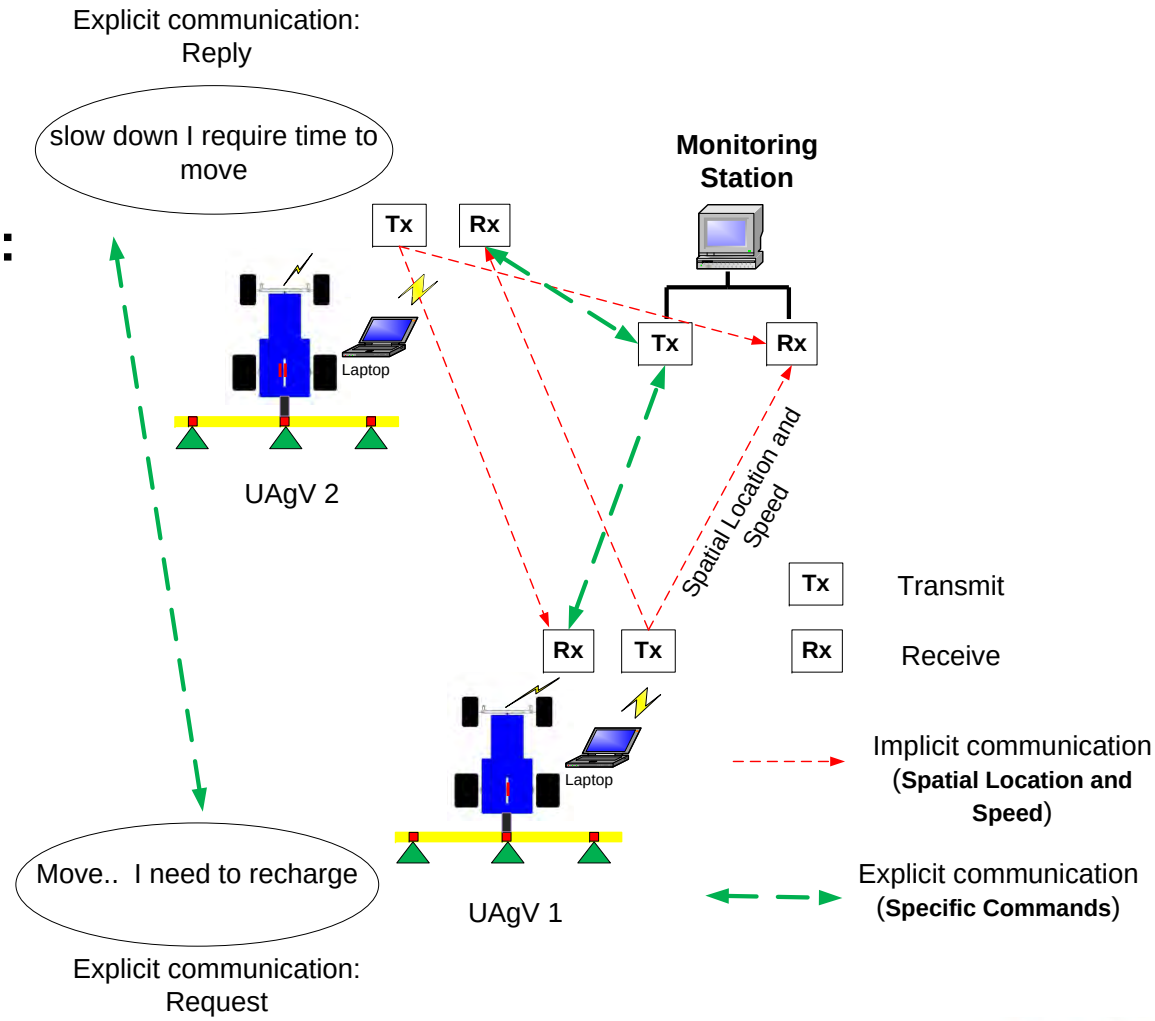
Wireless Communication

Implicit Communication:

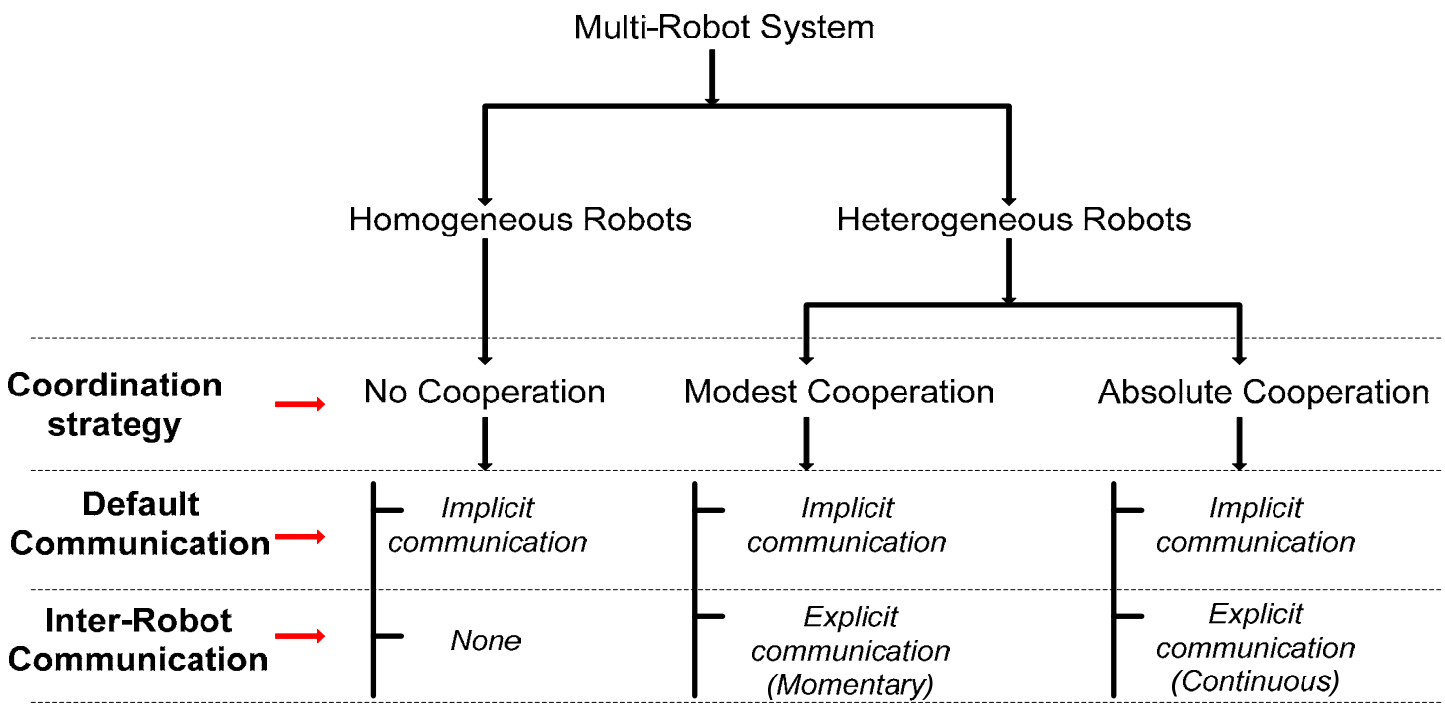
- States (x, y, θ)
- Velocities (V, ω)

Explicit Communication:

- Point to point communication of commands



MRS Coordination Strategy



The fusion of coordination strategy and inter-robot communication with IRCA constitutes the MRSCA.

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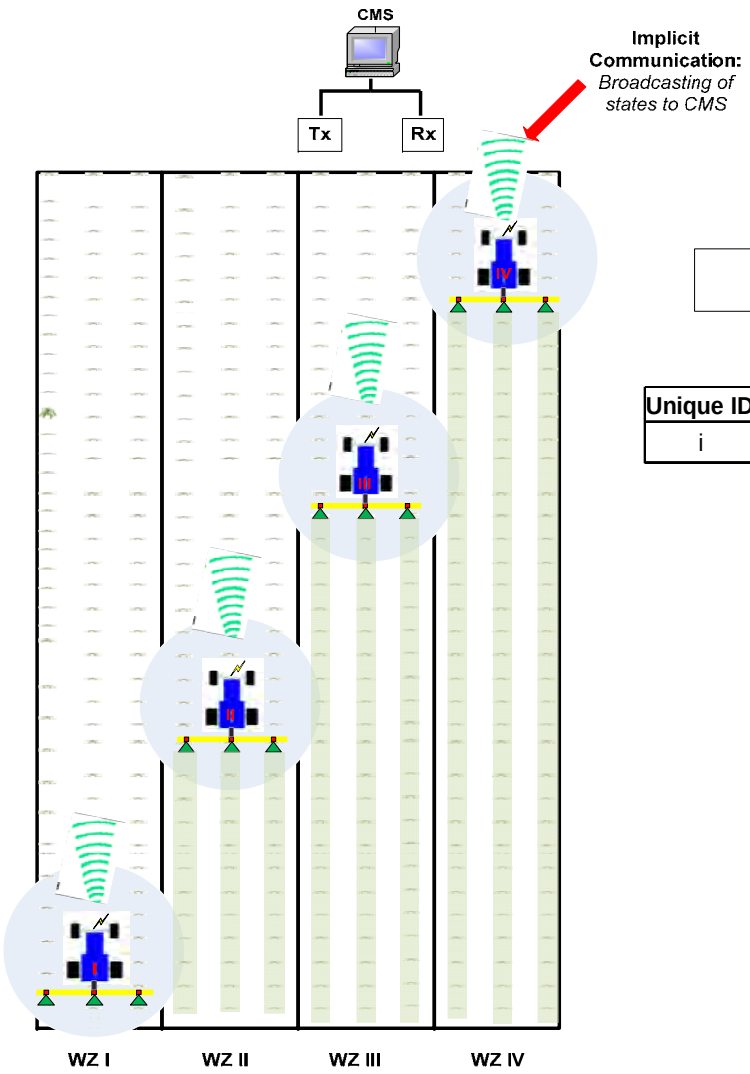
MRSCA for Agricultural Operations



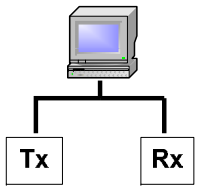
i =1 to 4

Robot i — Broadcast → CMS

Message Frame

Unique ID	States	Status	Time stamp
i	x_i, y_i, θ_i, v_i	% (a_i) area covered	t_i

CMS



		CMS database	
Unique ID	States	Status	Time stamp
1	x_1, y_1, θ_1, v_1	% (a_1) area covered	t_1
2	x_2, y_2, θ_2, v_2	% (a_2) area covered	t_2
3	x_3, y_3, θ_3, v_3	% (a_3) area covered	t_3
4	x_4, y_4, θ_4, v_4	% (a_4) area covered	t_4

Homogeneous MRS (no cooperation)

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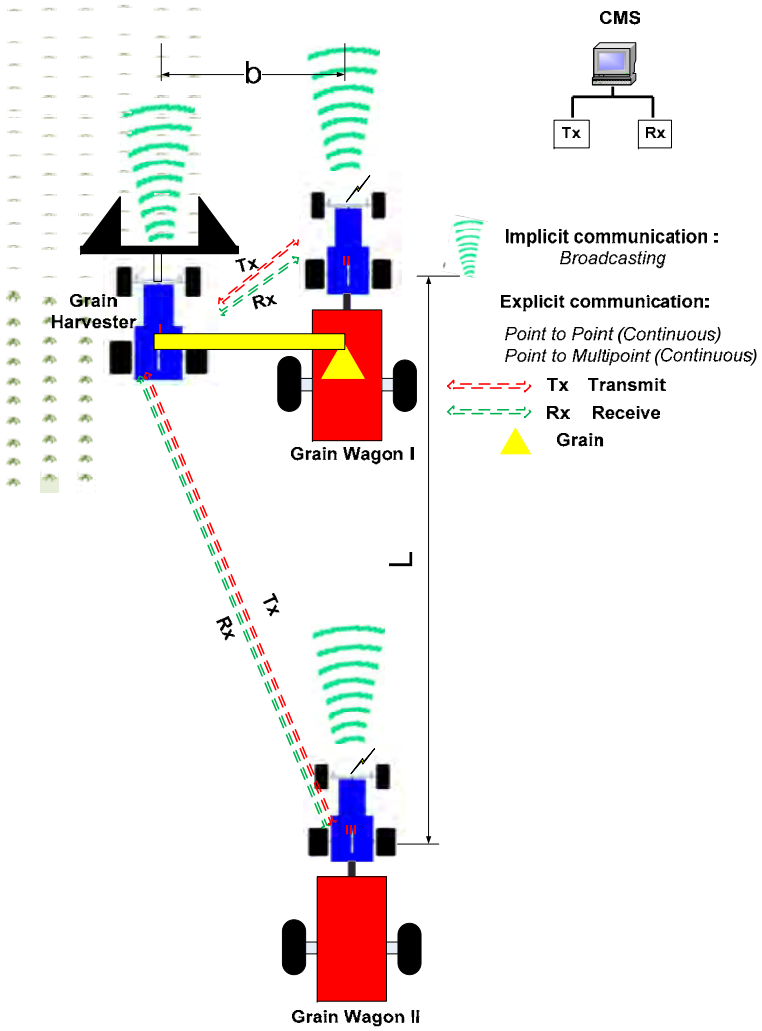
MRSCA for Agricultural Operations



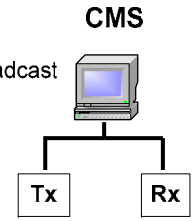
Tx-Message frame		Grain Harvester Robot (GHR)		
Unique ID	Destination ID	States	Time stamp	Status
1	2,3	$(x_1+b,y_1,\theta_1,v_1),(x_1+b,y_1-L,\theta_1,v_1)$	t_1	1,0
Onboard-message frame				
Unique ID	States	Status	Time stamp	
2	x_1,y_1,θ_1,v_1	1	t_1	Broadcast

Rx-message frame		Grain Wagon Robot I (GWR I)		
Unique ID	Source ID	States	Time stamp	Status
2	1	(x_1+b,y_1,θ_1,v_1)	t_1	1
Onboard-message frame				
Unique ID	States	Status	Time stamp	
2	x_2,y_2,θ_2,v_2	1	t_2	Broadcast

Rx-message frame		Grain Wagon Robot II (GWR II)		
Unique ID	Source ID	States	Time stamp	Status
3	1	$(x_1+b,y_1-L,\theta_1,v_1)$	t_1	0
Onboard-message frame				
Unique ID	States	Status	Time stamp	
3	x_3,y_3,θ_3,v_3	1	t_3	Broadcast

CMS database

Unique ID	States	Status	Time stamp
1	x_1,y_1,θ_1,v_1	1	t_1
2	x_2,y_2,θ_2,v_2	1	t_2
3	x_3,y_3,θ_3,v_3	1	t_3



Heterogeneous MRS (absolute cooperation)

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A few thoughts…

- Liability will require humans to remain on large machines
- Leader-follower systems will be common place for harvesting
- Point to point and point to multipoint communications will be essential

More thoughts…

- First autonomous tractors will be used in permanent crops
- Low-power vehicles will minimize liability
- Must develop intelligence - capacity to sense, assess and react to problems

Ideal Autonomous Tractor

- Low-draft applications (<30 kW)
- Light weight (<2,000 kg)
- Reduced design life (<5,000 h)
- Symmetry to minimize parts and service
- Green design, easy to recycle components

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Grazie!